BEAM TRANSPORT SYSTEM

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The Title I designs for the beam transport system—including the optomechanical systems, the spatial filter vessels and beam enclosures, and the laser bay and switch support structures—are dominated by the NIF's requirements for optical and mechanical stability and physical access. As Title II begins, we are ready to detail thousands of tons of structures, mechanisms, and vacuum vessels and to verify all analyses for detailed designs.

Introduction

The primary mission of the NIF's beam transport system is to support propagation of the laser beams. Our responsibilities include enclosing and supporting laser components up to the target area and positioning all the optics that transport the beam from mirrors LM1 to LM8. We transport the laser pulse through amplification and image-relaying components in the laser bays through the nine-story switchyards and into the target bay, where the pulse converges on the target.

A wide variety of hardware encloses, supports, or positions the major laser systems.[1] For instance, vacuum vessels and beam tubes enclose all beams between the preamplifier injection and the target room in a clean, light-tight environment. Steel and concrete spaceframes provide stable support for the optics and diagnostics in the laser bay and switchyard. Optomechanical systems point and center all full-aperture lenses, polarizers, and mirrors. All in all, we provide mounting and positioning for 768 spatial filter lenses, 768 laser bay mirrors, about 800 switchyard and target bay mirrors, and hundreds of shutters, injection mirrors, beam dumps, fiducials, windows, and 4 × 1, 2 × 2, and 2 × 1 handling cassettes.

Throughout the design, our efforts were dominated by requirements for optical and mechanical stability, physical access, and cleanliness. The stability requirements drove us to an intensive modeling and analysis effort to minimize system costs. Hundreds of hours of design tradeoffs led to the final Title I design of the beam transport system. Our designs accommodate bottom- and top-loading of handling cassettes and minimize structural footprints to allow room for electronic racks, sensor packages, and optics handling transporters.

Our design philosophy was this: simplify everything. For the laser bay structures and vessels, our design goal was to minimize job site activities by modularizing these components into the largest practical subassemblies so that these could be aligned, leak tested, cleaned, and assembled by the fabricators. In the switchyard, we depended on standard building erection techniques and details. For the optomechanical components, we were committed to making the line replaceable unit (LRU) philosophy succeed, to maximizing the use of mass production processes, and to consolidating component designs to use common parts.

Some areas within the facility, however, defy simplification. For instance, the transport spatial filter (TSF) area is a highly congested network of mirrors, light, and structures (Figure 1), and the switchyards are 30-m-high steel jungles encompassing diagnostics, pathways, mirror LRUs, and beam tubes.

[1] We do not discuss the auxiliary systems, which are also part of the beam transport system area. Auxiliary systems control the vacuum vessel and argon environments, and local power, lighting, and fire protection systems.

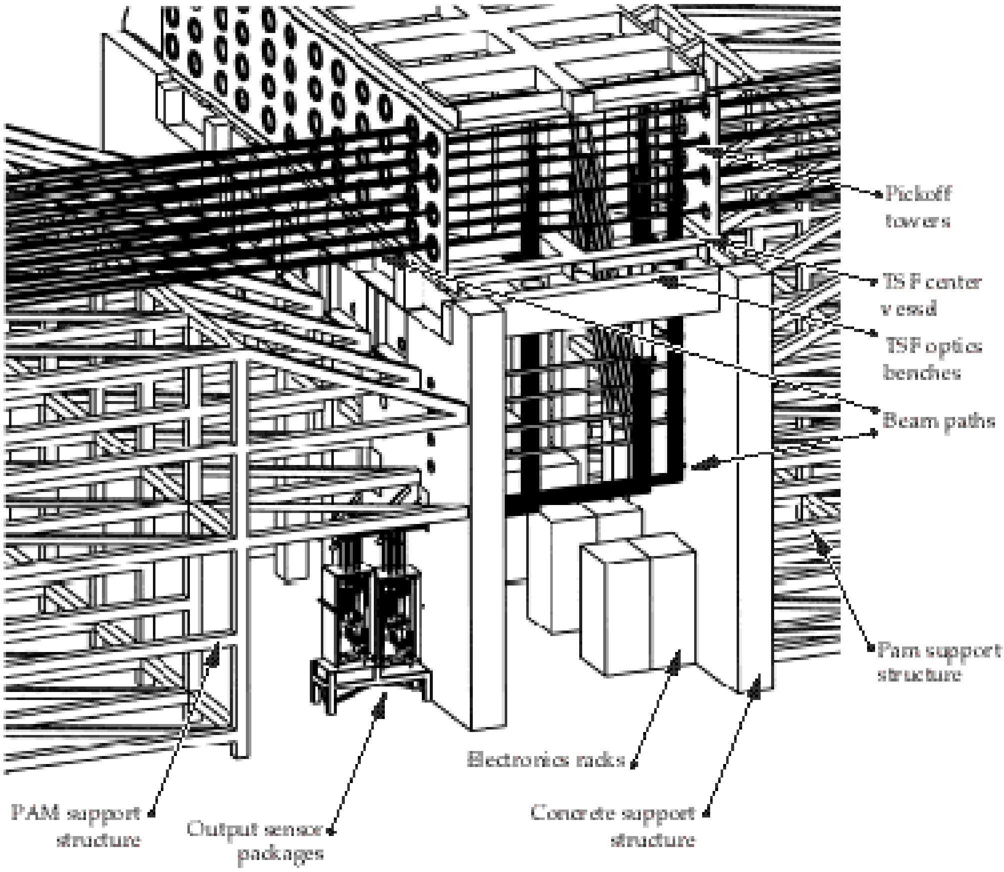

FIGURE 1. The transport spatial filter (TSF) plane area must accommodate numerous needs. (40-00-1097-2291pb01)

The rest of this article summarizes the design for the following:

- The laser bay and switchyard support structures.
- The vacuum vessels and beam enclosures.
- The spatial filter diagnostic/alignment tower structures.
- The optomechanical systems.

Laser Bay and Switchyard Support Structures

The function of the laser bay and switchyard structural support systems is to mechanically support the laser beam optics, optics vessels, beam enclosures, diagnostics systems, and utilities. The beam transport system also provides optical stability and seismic restraint and access pathways for service and maintenance. Optical stability is the controlling requirement in these areas.

The Title I design for the laser bay features hybrid concrete-steel structures for stability and ease of construction (Figure 2). These structures draw on the advantages of each material. Concrete's advantages are that it has higher mechanical damping properties, higher thermal inertia, and lower cost for simple shapes. The advantages of steel are that it is faster to install, easier to physically design around the laser, and easier to handle if the laser configuration changes, or if the laser is decommissioned, and it has a higher stiffness-to-weight ratio for structures.

Below, we describe the structural support systems for the laser bay and the switchyard. We begin with the major structural support subsystems of the laser bay, grouped as follows (see Figure 3):

- The LM1 support structure.
- The amplifier support structures (main amplifier support and power amplifier support).
- The periscope support structure.
- The spatial filter support structures (center-vessel supports and end-vessel supports for the cavity spatial filter and transport spatial filter, as well as the preamplifier support).

This section ends with the switchyard support structures.

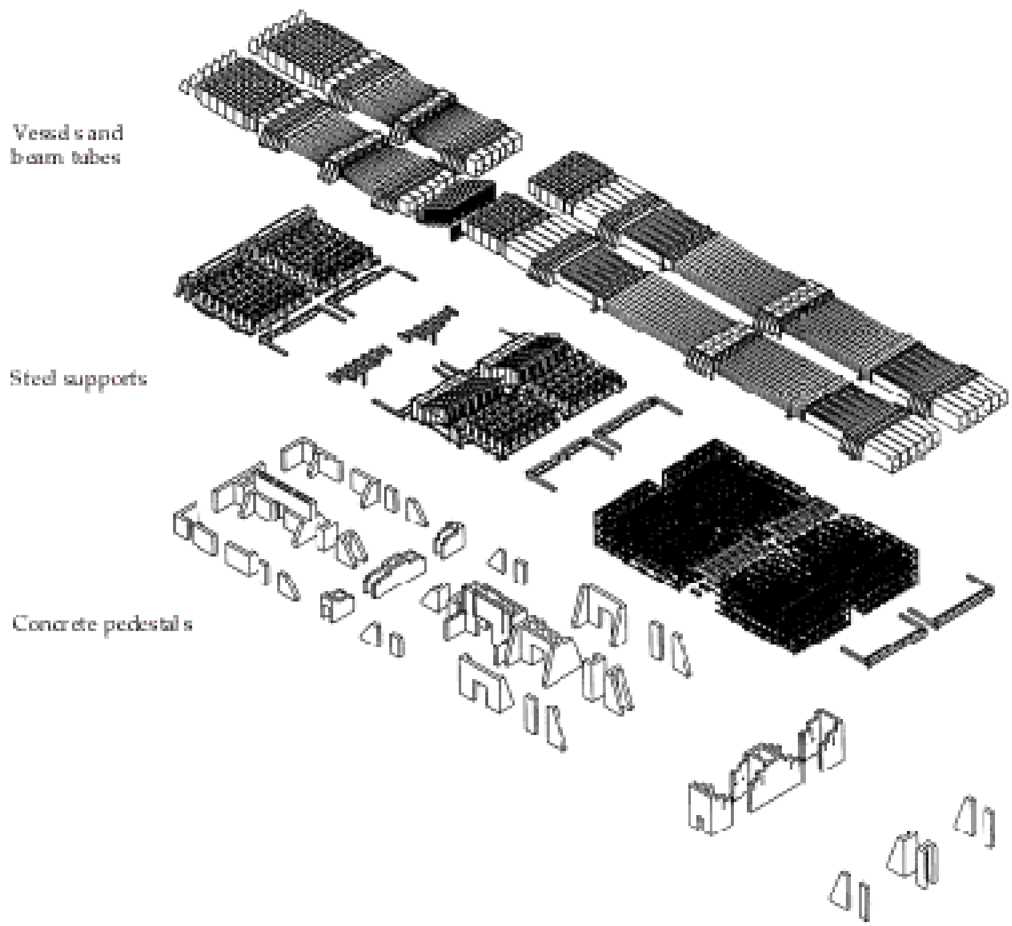

FIGURE 2. The hybrid concept uses concrete up to the height of the beamlines and steel surrounding the beamlines.
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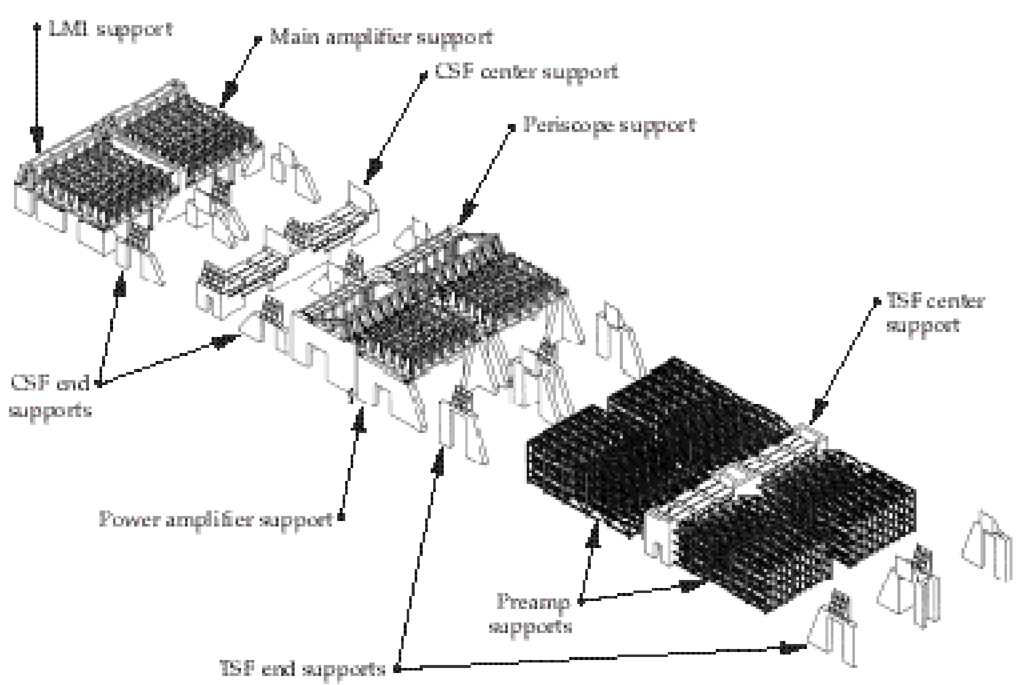

FIGURE 3. Layout of the nine major structural support subsystems in the laser bay.
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LM1 Support Structure

The support structure for the deformable mirror LM1 must provide pointing stability of ±0.42 μrad for the mirror and a stable mount for beam centering reference light sources used by the alignment system.

The structural design includes reinforced concrete shear walls and steel box beams, a welded modular construction, and an attachment to the superstructure through steel interface plates to the concrete shear walls. For each cluster, the concrete shear walls are 113 metric tons (m.t.), the steel superstructure is 34 m.t., and the cassettes with optics are 6 m.t. The structure is designed using standard catalog structural steel shapes and 61-cm-thick concrete shear walls with embedded steel interface plates. The optical LRUs are supported directly by the superstructure—separate array frames are unnecessary—and the welded module size will consist of one-half of the superstructure, to minimize bolted joints and on-site assembly time. Gas enclosure plates are attached to the superstructure to provide added stiffness, and main utility runs and interstage enclosures are supported by the structure. The optical LRUs are attached to supports on the superstructure through adjustable kinematic mounts. Electric motor and fiber-optic connections attached to the bottom enclosure plates provide for cassette mirror movement, mirror deformation, and deformed shape feedback. Figure 4 shows front and side views of the LM1 support structure, along with its components.

To meet cleanliness requirements, all carbon steel is painted, bundles have partitions between them to prevent any possible cross-contamination, and a slight positive pressure is maintained inside the enclosure to prevent room air intrusion. Outside the enclosure, LRU operations provide sealing to the bottom grid plate to maintain internal cleanliness, and interstage enclosures maintain cleanliness between the optical structures.

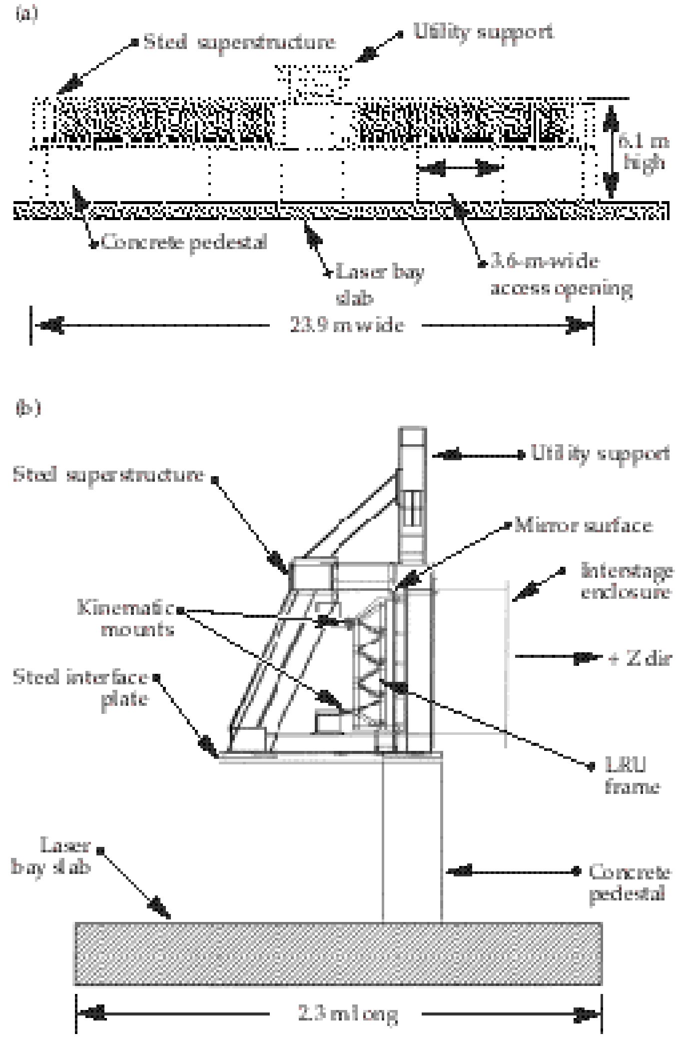


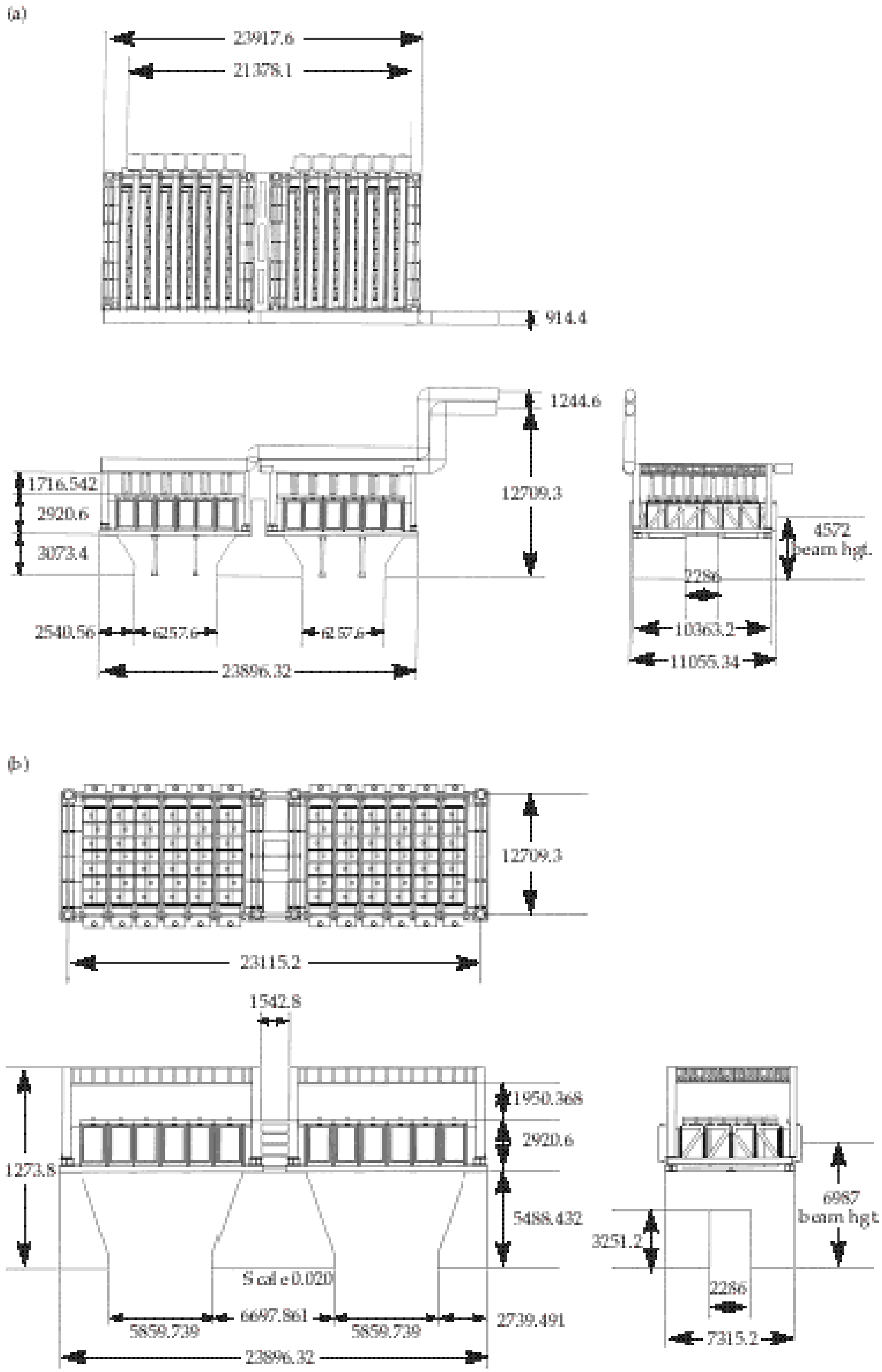
FIGURE 4. The LM1 support structure is 23.9 m wide, 6.1 m high, and 2.3 m long in the beam direction. Two views, (a) front and (b) side, show the components of this structure. (40-00-1097-2293pb01)

Amplifier Support Structures

The amplifier design includes two support structures: one each for the main and power amplifiers. The amplifier support structure must support the amplifiers, flashlamps, utilities, flashlamp cooling system, amplifier nitrogen system, and power cables. The structure must provide a translational stability limit of 500.0 μm, and a rotational stability limit of 2000.0 μrad. There must be a cleared area on the floor, 193 × 193 cm, centered under each LRU cassette position in the amplifier to allow clearance for the LRU transporter and a vertical clearance of 325 cm for the bottom loader. In addition to meeting the standard seismic requirement, this support must do so with no breaking glass, falling hardware, or colliding components.

The hybrid concrete-steel design for the amplifiers uses a total of 1005 m.t. of reinforced concrete for the pedestals and 363 m.t. of structural steel for the superstructures. The reinforced concrete shear walls are 56 and 61 cm thick and are integral with the facility's floor slab. The structural steel consists of wide-flange and tube-steel sections in a welded modular construction; the dimensions of the support system for the main and power amplifiers are shown in Figures 5(a) and 5(b), respectively. This design permits top loading for the initial installation and bottom loading for the amplifier cassettes during normal maintenance. It also allows a

FIGURE 5. Dimensions for (a) the main amplifier support structure and (b) the power amplifier support structure. All distances are in millimeters. (40-00-1097-2294pb01)



single frame-assembly unit (FAU) to be removed and replaced. The amplifier top plate is a structural element for the support structure, and the amplifier bundles are electrically isolated from each other and the support structure.

Periscope Support Structure

The periscope support structure supports the plasma electrode Pockels cell (PEPC), the polarizer, the LM2 and LM3 mirrors, the reference point sources for centering, and interstage beam enclosures. It must provide ≤0.60 μrad pointing stability for double reflections from LM3 and the polarizer, and ≤0.70 μrad pointing stability for a single reflection from LM2.

The design uses standard steel structural shapes, and 56- and 61-cm-thick concrete shear walls. The structure is 23.9 m wide, 8.9 m high, and 9.3 m long in the beam's direction. Its total weight, including the concrete walls, optics, superstructure, array frames, utilities and interstage enclosures is 697 m.t. To meet cleanliness requirements, we will paint the steel, provide partitions between optic bundles, and provide a slight positive pressure inside the enclosure. The PEPC, LM3/polarizer, and LM2 LRUs are attached to the superstructure through kinematic mounts. The reference light source is mounted onto the superstructure; PEPC utility-line interfaces are provided on the structure; and main utility runs for the building interface to the periscope center structure. Two views of the structure are shown in Figure 6.

Spatial Filter Support Structures

The spatial filter support structures, located at opposite ends of the laser bay, support the spatial filter lenses, the pinhole and diagnostics/alignment towers, the vacuum vessels, the beam enclosures, the injection and diagnostics systems, and the utilities. There are three separate structures in each spatial filter support system—a center-vessel support structure and two end-vessel support structures. The center-vessel support structure holds the center vacuum vessel and pinhole towers, utilities, and beam tubes (the TSF also has a space frame to support the preamplifier system). On either end of the center structure, two end-vessel support structures hold the spatial filter end vessels, utilities, and beam tubes.

The cavity spatial filter (CSF) lenses, SF1 and SF2, require a centering stability ≤6 μm; the transport spatial filter lenses, SF3 and SF4, require centering stability ≤0.7 mm. The structures must provide a 193 × 193-cm clear footprint and a 325-cm vertical clearance for the bottom loader.

The design uses the hybrid concrete-steel concept for all support structures except the preamplifier support, which is entirely structural steel. We use a total of 1673 m.t. of concrete in the pedestals and 725 m.t. of steel in the superstructures. The reinforced concrete shear walls are 56 and 61 cm. thick, integral with the facility's slab. The steel frame is of welded construction and uses standard catalog structured steel shapes. The structure is welded in truckable units at the fabricator's facilities and assembled on-site with bolted moment-resisting joints. Figures 7 and 8 show the plan and elevation of the TSF and CSF support structures.

The close-packed array of preamplifier modules requires an all-steel spaceframe (Figure 9). The structures are fabricated in truckable modules and assembled on-site with bolted moment-resisting joints. The steel frame is of welded construction and uses standard catalog structured steel shapes. The maximum module size is 6 × 2.4 × 3 m and the maximum weight is 3.5 m.t.. The total weight of the PAM support structures is 562 m.t.

Switchyard Support Structures

Each of the two switchyards has one 544-m.t. steel spaceframe (Figure 10). The spaceframes are attached to and stabilized by the target building concrete walls and the switchyard shield walls. The Title I steel switchyard structures are designed for a six-tier laser beam layout. The 27.4-m-tall spaceframe is coupled to the concrete building to optimize stiffness and cost. The spaceframe must accommodate the laser beam layout in the target and laser bays; must allow correct placement of LM4 and LM5 mirror assemblies, beam enclosures, and laser diagnostics; must not preclude a secondary target chamber; must provide <0.7 μrad angular and ≤1 mm translational stability over two hours for the mirrors.

The spaceframe design for each switchyard has eight levels and 20 columns and uses standard 12 × 20-in. tubular-steel horizontal members and 12 × 12-in. tubular-steel columns. The box on p. 154, "The Eight Levels of the Switchyards," provides more information about the layout of each floor.

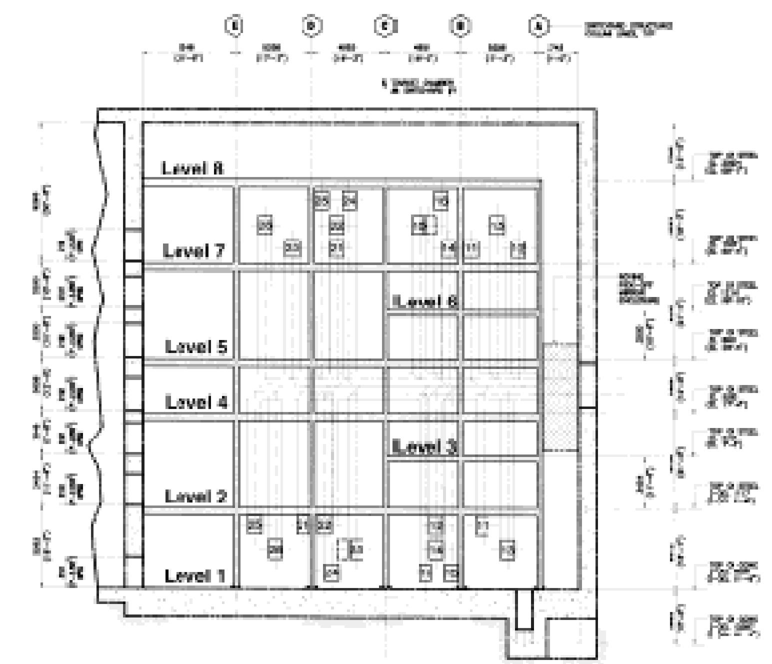
THE EIGHT LEVELS OF THE SWITCHYARDS

As the figure in this box shows, the eight levels of the two switchyards are similar in layout, but not identical. The first two levels are below floor level.

Level 1 (elevation –6.6 m) in each switchyard has a concrete floor with 20 columns of 12 × 12 in. structural tubes. Twelve quads are mounted in three tiers: five quads mounted to the floor above, four quads mounted to the floor above and concrete floor below, and three quads mounted to the concrete floor. Nine quads in each switchyard at this level require platforms for maintenance purposes. There is a 1.8-m-wide access pathway to all quad locations, and there are collimators in 3.6-m-thick concrete walls at beam tube locations.

Level 2 (elev –1.1 m) has the largest area of grating. Twelve vertical beam tubes are in each switchyard at this level. Five LM5 quads in each switchyard are mounted immediately below this level. The spaceframe connects to the concrete building in five places at the target bay, two places at the switchyard stairwell, and two places at the switchyard corners. The precision diagnostics vessel is located in switchyard #2 at this level.

Level 3 (elev +2.4 m) has concrete mezzanine floors, which are part of the target bay, for classified electronics racks. Lateral supports for 12 vertical beam tubes are in each switchyard, and maintenance platforms provide access to the bottom of the LM4s located on the floor above.



Layout of the eight levels in the switchyards. (40-00-1097-2312pb01)

Level 4 (elev +5.3 m) has 24 LM4 quads mounted in two tiers in each switchyard. This level also includes the roving pick-off mirror enclosures. The spaceframe connects to the concrete building in the same manner as on level 2.

Level 5 (elev +9.0 m) has LM4 maintenance platforms and provides access to 12 LM4 quads mounted immediately below. It is also the top of the roving pick-off mirror enclosures. The spaceframe connects at this level in the same manner as at levels 2 and 4.

Level 6 (elev +12.2 m) has concrete mezzanine floors for classified electronics racks. It also has lateral supports for 12 vertical beam tubes in each switchyard.

Level 7 (elev 15.4 m) has 12 LM5 quads mounted in three tiers: three quads mounted to the floor above, four mounted to the floor above and the level 7 floor, and five mounted to the level 7 floor. Seven quads in each switchyard require platforms for mirror maintenance. There are also collimators in 3.6-m-thick concrete walls at the beam-tube locations. The spaceframe connects to the concrete building in the same manner as at levels 2, 4, and 5.

Level 8 (elev +20.9 m) has three LM5 quads mounted immediately below. This level has no access and no grating. The spaceframe connects to the concrete building in the same manner as at levels 2, 4, 5, and 7.

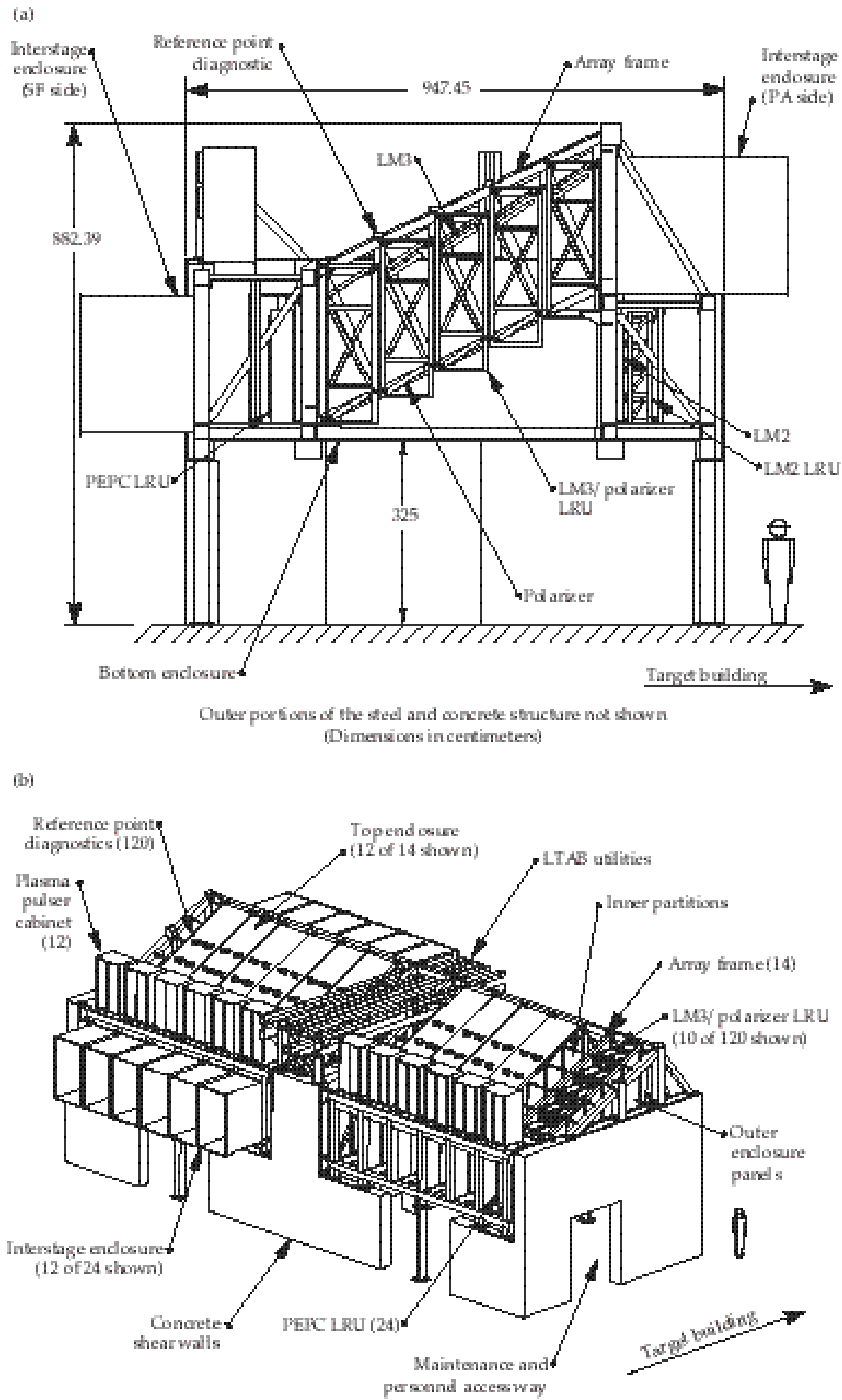
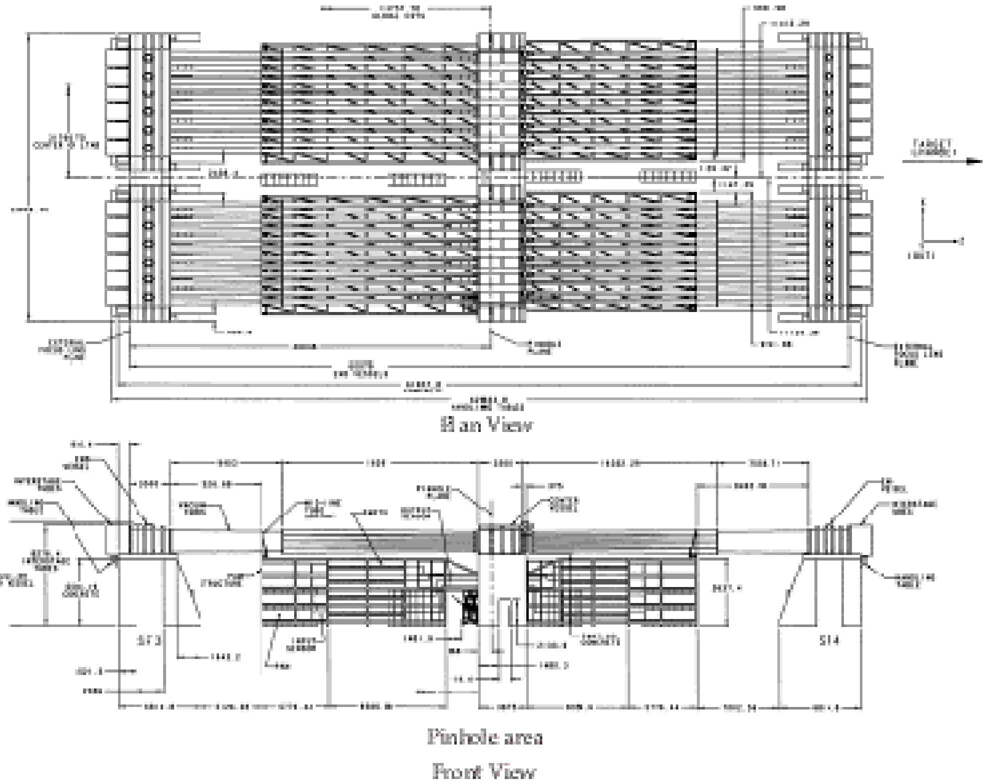


FIGURE 6. (a) An elevation view of the periscope structure and (b) a view showing the concrete and steel outer structure. (40-00-1097-2295pb01)

FIGURE 7. Plan and elevation of the TSF support structure. All distances are in millimeters. (40-00-1097-2296pb01)



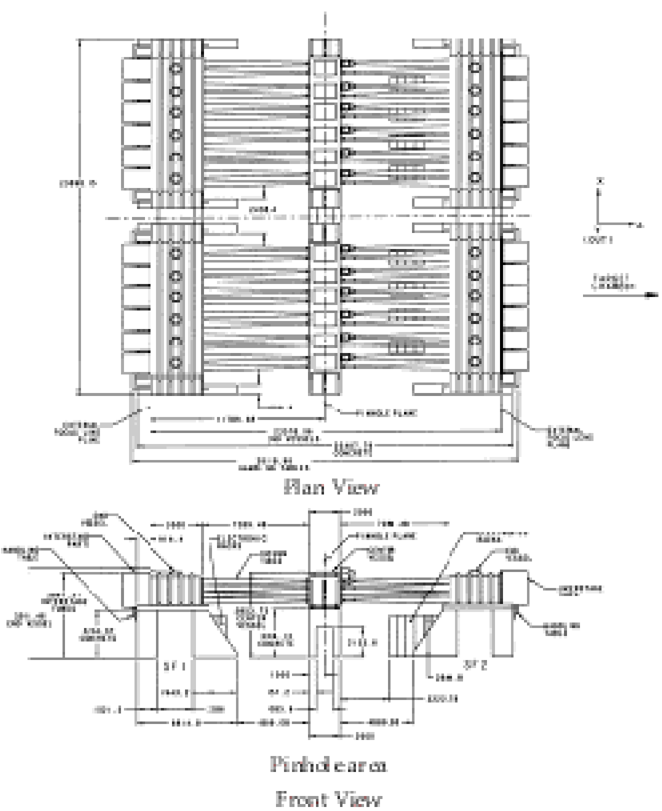


FIGURE 8. Plan and elevation of the CSF support structure. (40-00-1097-2297pb01)

Vacuum Vessels and Beam Enclosures

The vacuum vessels and beam enclosures are a major part of the NIF laser system infrastructure. They contain propagating laser beams and optomechanical hardware in a contamination-controlled environment in the facility and are positioned to allow top and bottom access (Figures 11 and 12). The primary functions of the enclosures and vessels are to safely contain laser beams within the required environment, allow access for removing LRUs, provide interfaces for preamplifier beam injection and laser diagnostics, achieve position and stability requirements within budgeted tolerances, and provide independent bundle operation. In our design, we also considered the surface finish—for cleanliness and ease of cleaning—and the size and weight of the pieces to meet transport and installation requirements.

The spatial filters are stainless steel vacuum vessels interconnected by tapered beam tubes with bellows at the center vessels (Figure 13). The tapered tube/bellows arrangement allows air flow to minimize thermal gradients. Each 60-m transport spatial filter cluster is nearly 275 m.t. of stainless steel. The

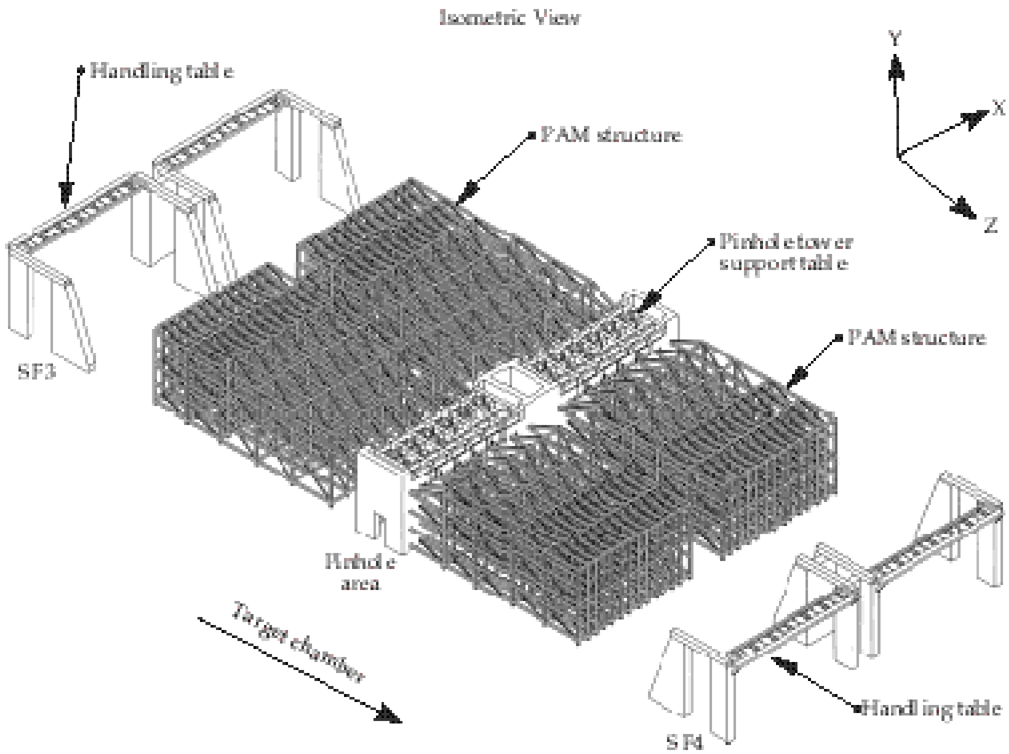


FIGURE 9. An isometric view of the preamplifier spaceframe. (40-00-1097-2298pb01)

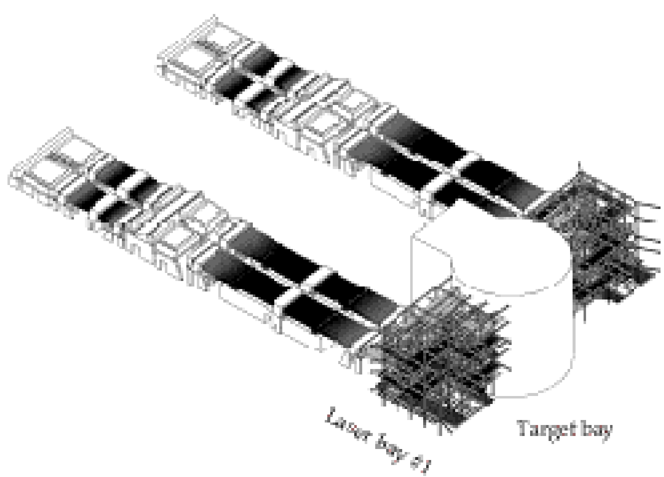


FIGURE 10. The switchyards in relation to the laser bays and target bay. (40-00-1097-2299pb01)

23.5-m cavity spatial filter cluster has a smaller center vessel and weighs 142 m.t. The TSF and CSF end vessels are identical. The end vessels are optics benches for 4 × 1 lens arrays; each array provides a vacuum boundary. The center vessels allow top loading of the pinhole / diagnostic tower LRU (see next section on tower structures).

Beam enclosures include the special tapered tubes between the center and end vessels; the interstage beam enclosures between the amplifiers, vessels, and so on; and the beam enclosures in the switchyard.

The tapered stainless steel tubes between the center and end vessels were designed to minimize mass, to increase system stability, to reduce costs, and to allow 10-mm minimum clearance between the tube inner diameter and the full-aperture beam. In addition, the beam spacing within each bundle limited our design configuration. The limited vertical space between laser beams required rectangular tubes at the TSF end vessels. For this, we use 8-mm 304 stainless steel sheet, which is brake-formed into tapered U-shapes and welded together to form bundles. Circular tapered beam tubes are used in areas without space constraints. We used finite-element analysis to evaluate the stress and deflection due to the vacuum load and found that the spatial filter vessel and tapered beam tube designs are within allowable stress and deflection limits.

Interstage beam enclosures (IBEs) enclose the beams in bundles between the amplifiers, vessels, and so on. The IBEs are rib-stiffened, welded stainless-steel sheet-metal enclosures. They are made of 12-gage stainless-steel sheet, with carbon steel external stiffeners, and have shielded elastometric 50-mm bellows / expansion

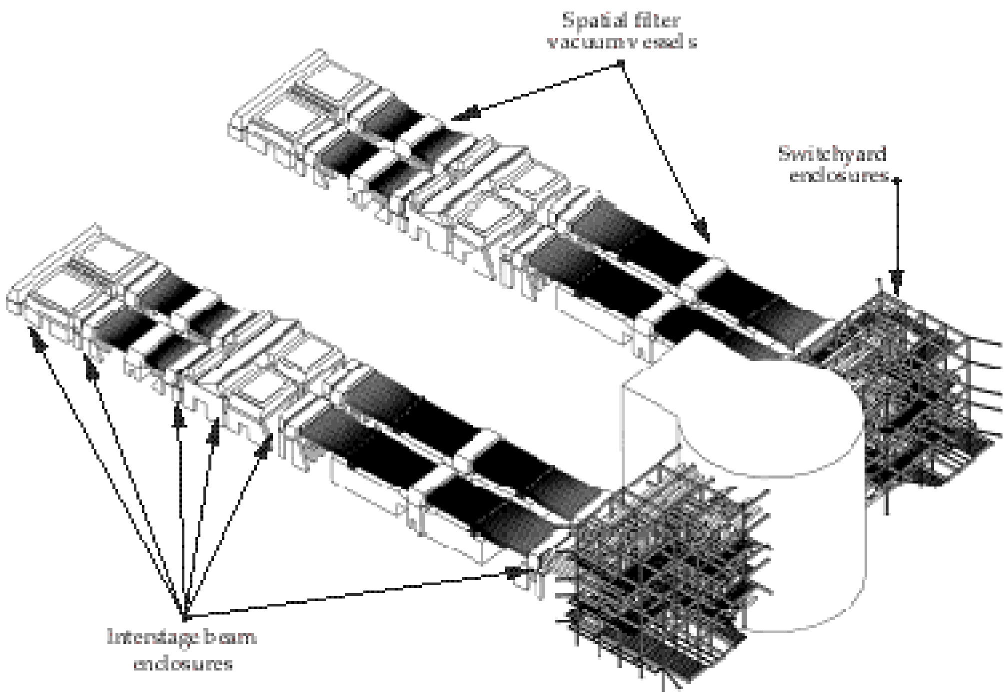


FIGURE 11. Location of the spatial filter vacuum vessels, interstage beam enclosures, and switchyard enclosures. (40-00-1097-2300pb01)

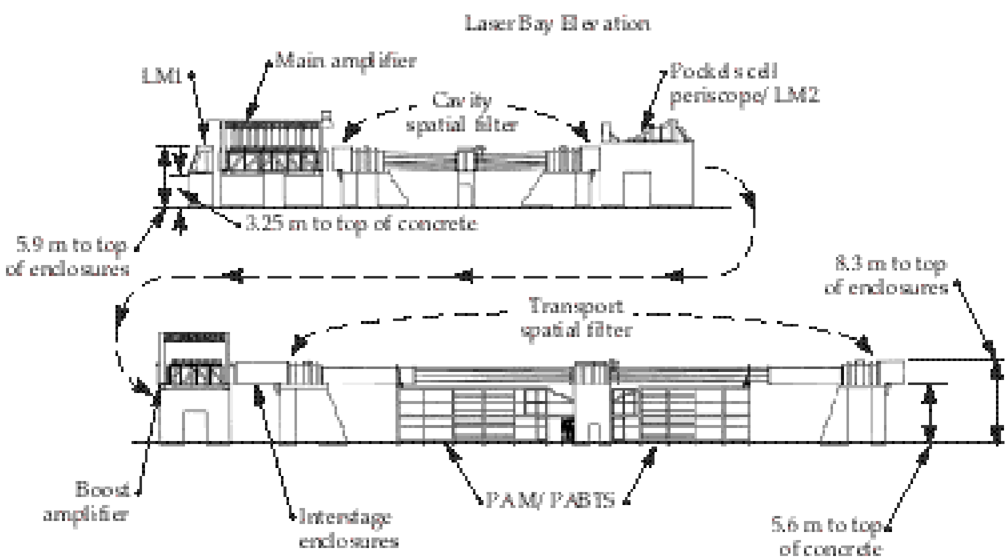


FIGURE 12. Enclosures and vacuum vessels are positioned to allow bottom access. (40-00-1097-2301pb01)

joints. An “eggcrate” baffle divides the beamlines within the IBEs.

Rib-stiffened sheet-metal beam enclosures also contain the laser beams in the switchyard area. In the switchyard alone, nearly 2000 m of sheet-metal beam enclosures provide a clean, argon-filled atmosphere for the beams. Each unique beamline has a different enclosure configuration (Figure 14). These enclosures also provide the interface with the LM4 and LM5 turning mirror boxes.

Spatial Filter Diagnostic/ Alignment Tower Structures

We use similar tower structure designs in the transport and cavity spatial filters (Figure 15). These designs are based on an isolated kinematic mount design that meets alignment and stability requirements. An external “optic bench,” located under the center vacuum vessel, provides

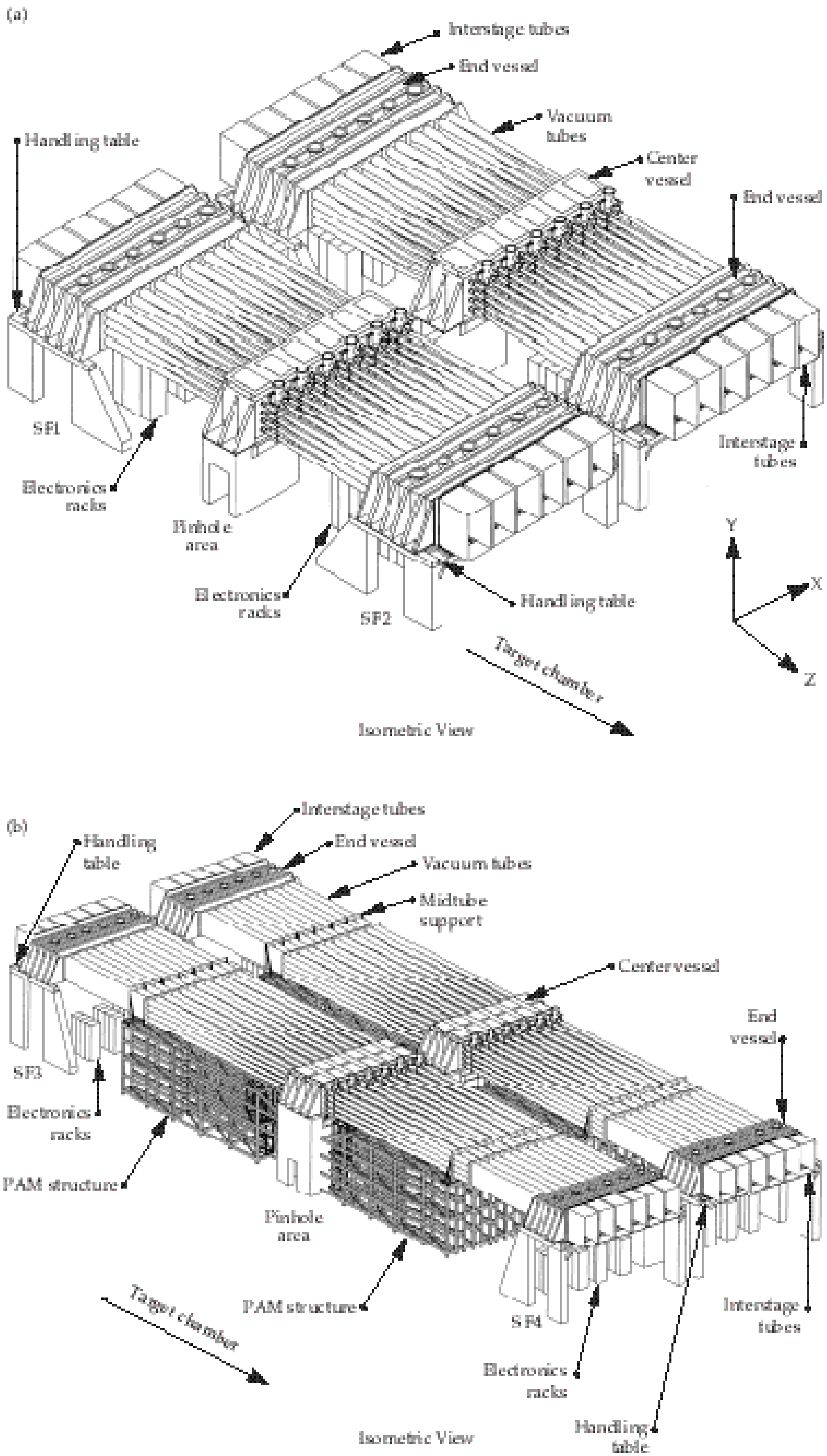


FIGURE 13. Layout of (a) the CSF support structure and (b) the TSF support structure. The CSF structure is a modified design of the TSF structure. (40-00-1097-2302pb01)

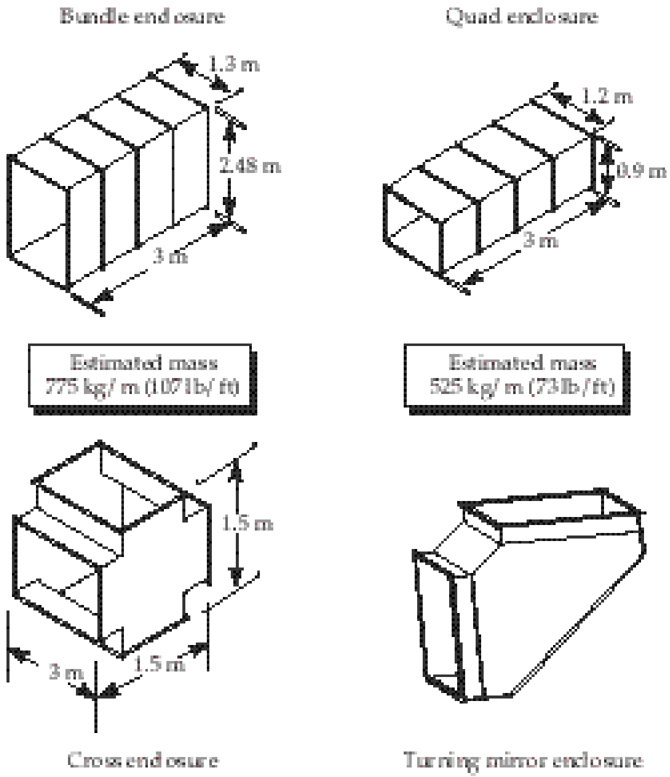


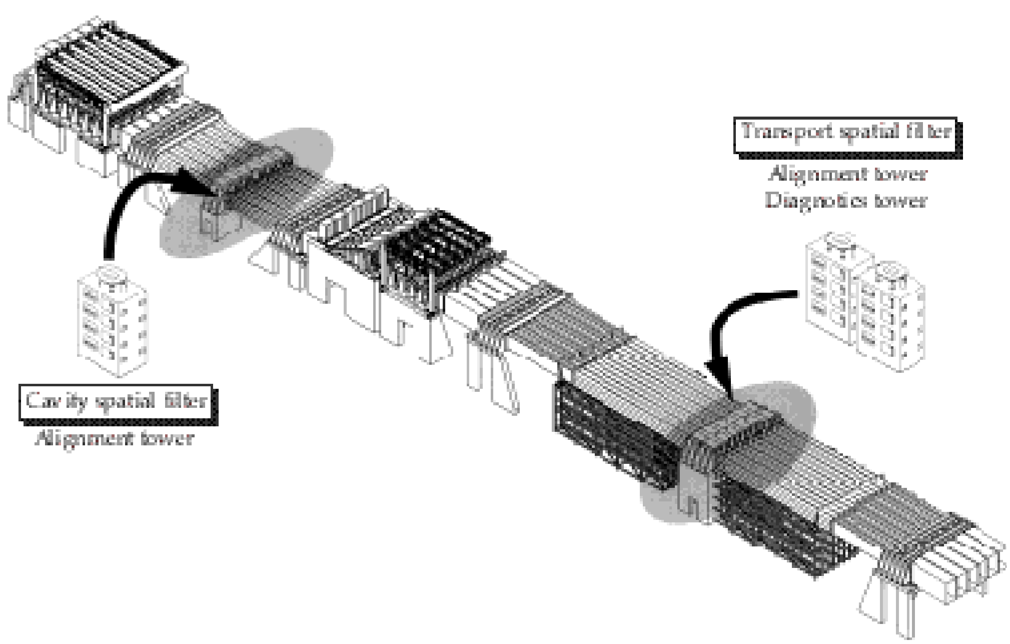
FIGURE 14. Some of the beam-enclosure configurations in the switchyard. (40-00-1097-2303pb01)

stable mounts for kinematic supports. The mounts are isolated from the vessel wall with bellows. The kinematic mounts provide a registered location for LRUs and will have either a cone-vee-flat or three-vee configuration. These mounts allow the towers to be decoupled from vacuum vessel pumpdown deflections (Figure 16). The spatial filter tower structures are designed for stiffness, with stainless-steel welded spaceframes, shear panels, and 25-mm-thick aluminum mounting plates that are individually shimmed and fastened.

Optomechanical Systems

NIF's optomechanical systems are located in the laser bays, switchyards, and target area (Figure 17). These systems consist of more than 2500 optical mounts: 384 cavity end mirror mounts, 384 polarizers and elbow mirror mounts, 768 spatial filter lens mounts, 192 spatial filter lens mounts, 192 injection mirror and telescope assemblies, 816 transport mirror mounts, and 192 shutter and beam dumps. These optomechanical systems must satisfy a number of diverse requirements. Multipass mirrors must have rotational stabilities of 0.6 μrad; CSF lenses must have translational stabilities of 6 μm; mirror-mount assemblies must have an angular adjustment step size of 0.1 μrad; and optical mount assemblies in LRUs must

FIGURE 15. Tower structure locations and design for the CSF alignment tower and the TSF alignment and diagnostic towers. (40-00-1097-2304pb01)



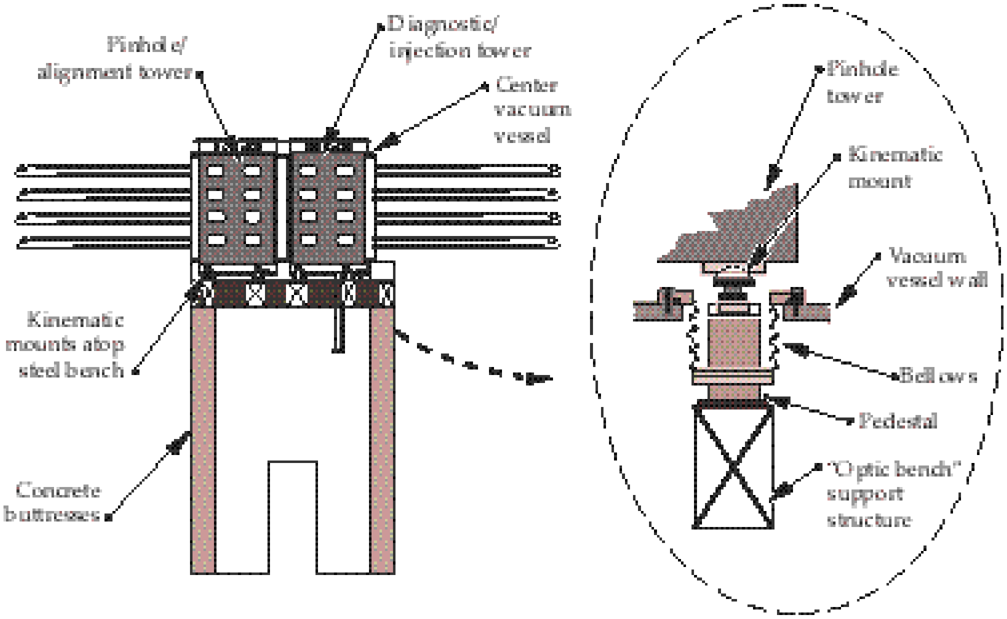


FIGURE 16. Towers are decoupled from vacuum vessel pumpdown deflections. (40-00-1097-2305pb01)

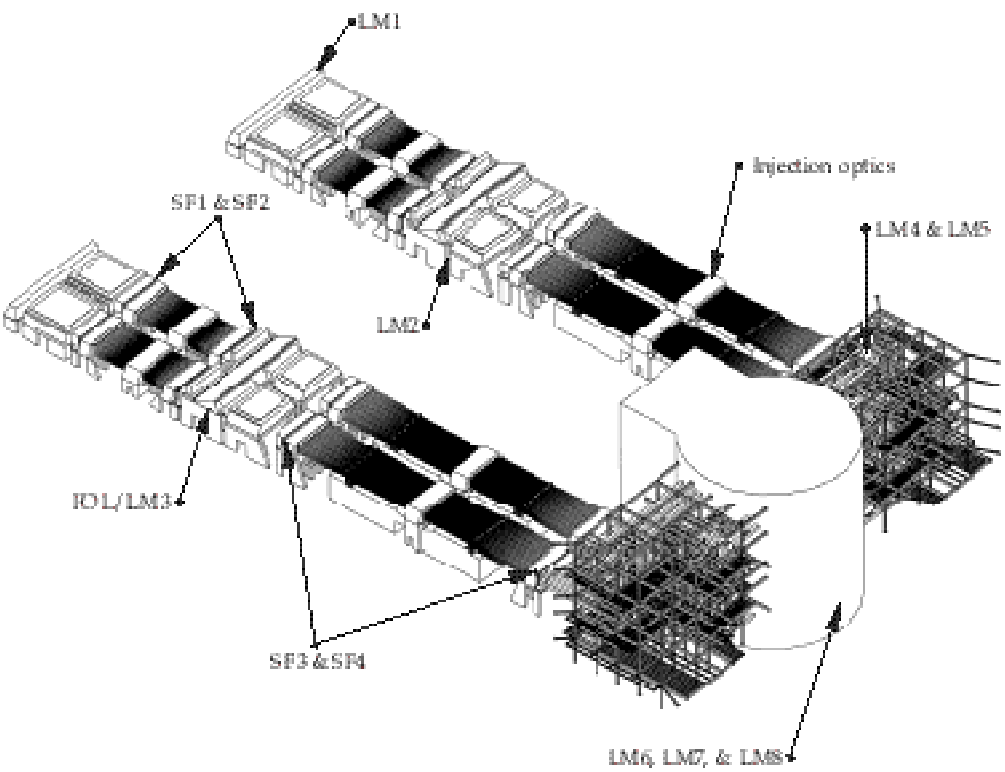


FIGURE 17. Location of NIF's optomechanical systems. (40-00-1097-2306pb01)

meet cleanliness and maintenance requirements. In the rest of this section, we describe the mounting designs for the cavity mirrors and periscope assembly, the spatial filter optics, and the switchyard and target area optics.

Cavity Mirrors and Periscope Assembly Mounting

The LM1 and periscope structures hold LM1, LM2, LM3, and the polarizers, and have the most critical stability requirements in the laser bay. All of these optics have tip-tilt adjustments to steer the beams through the chain.

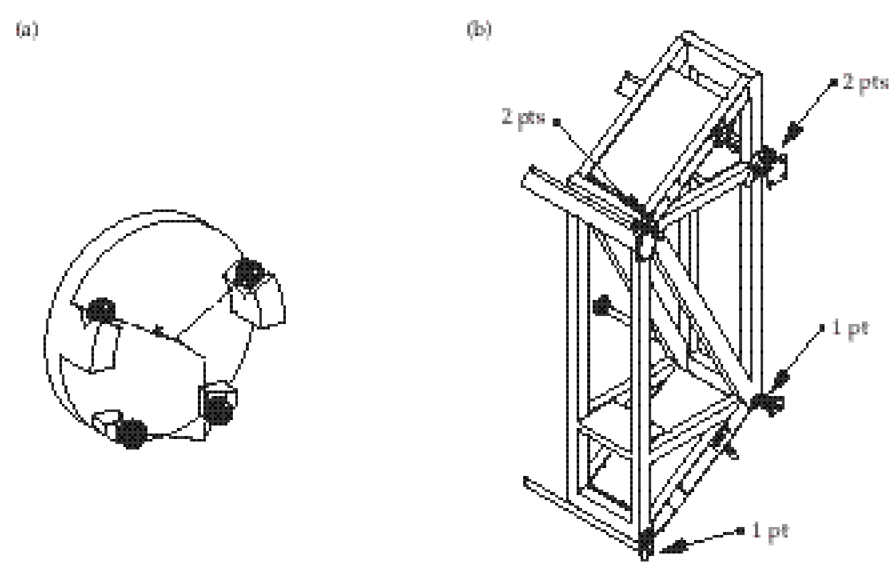
The LM1 structure for each cluster supports twelve LM1 LRUs, each containing four LM1s. The periscope structure supports twelve LM2 LRUs and 30 LM3/polarizer LRUs. The mounts for the cavity and periscope LRUs are gravity loaded and based on accepted kinematic principles (see box "Laser Bay LRU Kinematic Mounts" below). These mounts have pneumatic pins that retract for loading and a seismic restraint that retracts when lifted.

The LM1 deformable mirrors are on the front face of the LM1 LRU. Pigtails with pin connectors route through the frame to a panel below. The panel is accessible from the laser bay to plug in pin connectors and to splice the fiber optic.

The close spacing of LRUs means limited space for LRU mounts, mirror mounts, cover seals, and clearance for insertion. The LM2 mirrors install from the front, and Fresnel lenses mount in the frames that attach to the LRU. The LM3/polarizer optics install from each end: the LRU is inclined so that the optics install vertically. Each of the three optics has a tip-tilt

LASER BAY LRU KINEMATIC MOUNTS

The laser bay LRU kinematic mounts—which evolved from a typical three-vee kinematic coupling—have been designed to constrain exactly six degrees of freedom with six theoretical points of contact as shown in the figure. The LRUs hang from two upper vees and brace against one lower vee for six-point support. A pneumatic pin engages two ball swivels to form the upper vee constraint, while the widely spaced spherical pads that form the lower vee passively engage upon insertion. For the upper vee, a molded Teflon seal and low-outgassing grease minimize contamination.



(a) A NIF LRU mount; the lower widely spaced pads form the lower vee. (40-00-1097-2313pb01)

(b) LRUs hang from the two upper vees and brace against one lower vee for six-point support.

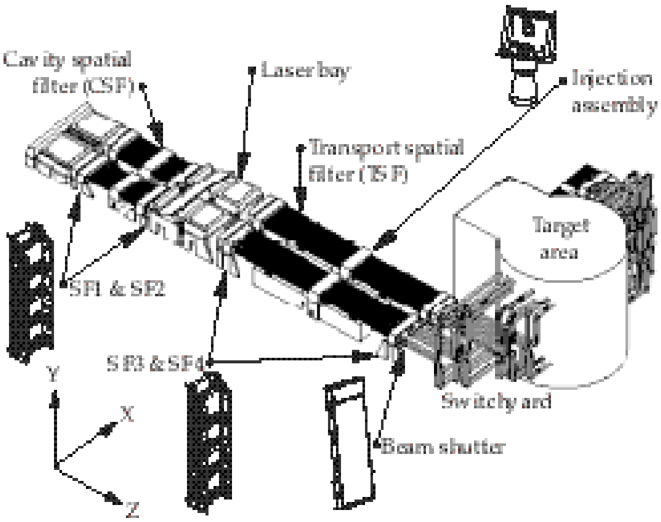


FIGURE 18. The location of the spatial filter optomechanical systems. (40-00-1097-2307pb01)

mirror mount that supports the optic at three points with ball pivot connections. Each ball pivot constrains two degrees of freedom (DOF). These optics show an insignificant amount of gravity-induced deformation.

Spatial Filter Optics Mounting

There are 768 spatial filter lenses, 192 injection mirrors, and 24 beam shutters within NIF (Figure 18). For the spatial filter lens LRUs, the fixed-optic center spacing and lens dimensions leave little space for mounting hardware. For spatial filters SF1 through SF3, the tight vertical lens spacing drives the design; SF4 has an additional design challenge of an optical / mechanical center offset (Figure 19) to avoid ghost-beam back reflections. In addition, the mechanical clear aperture of each lens is limited and is a factor in the mount design. Finally, each spatial filter lens position has a challenging set of positioning accuracy requirements. The positioning requirements for

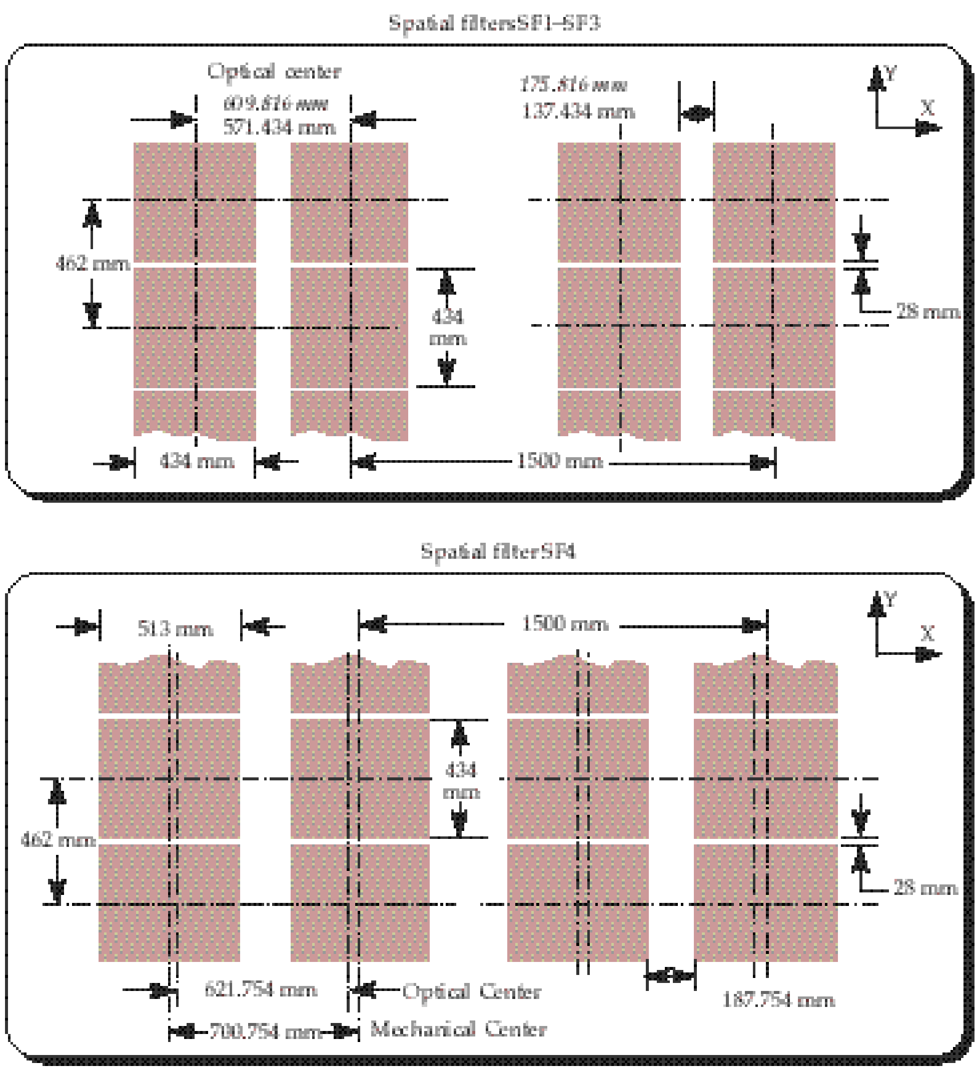


FIGURE 19. Fixed-optic center spacing and lens dimensions leave little space for mounting hardware for the four spatial filters. Italics denotes SF1 and SF2 values. (40-00-1097-2308pb01)

SF1 through SF3 are met by maintaining fabrication tolerances. After assembly, only the SF4 cassette requires additional tip / tilt alignment, using a bellows and adjustment bolts.

The injection mirror and beam shutter are two of the many optomechanical devices located in the TSF area. We added an injection telescope to the injection mirror (Figure 20) to maintain relay planes and the proper cone angles. It must accept a full-aperture beam, withstand a full-fluence shot, contain debris, detour back-reflection off-axis, be remotely inserted and removed without releasing beam tube gases, and fit within a small area. Figure 21 shows the layout of the shutter. An array frame contains eight beam shutter cells to block a laser bundle. Each shutter cell has a 2° tilt to send any back-reflections onto additional beam blocks. The array frame is connected to a linear translator within an air-tight enclosure, and the cell array is enclosed to preserve cleanliness and to contain beam-line gases. The beam shutter enclosure is secured in position by two supports: brackets are bolted to the floor frame and the shutter spool is bolted to the structure frame.

Switchyard and Target Area Optical Mounts

In the switchyard, mirrors LM4 and LM5 transport the beams from the laser bay through the switchyard to the target bay. The LM4 quads direct the beam up or down; LM5 quads direct the beam horizontally to the target chamber. In the target bay, mirrors LM6 through LM8 direct the beam to the final optics assembly at the target chamber. The switchyard and target area mirrors share many requirements: the total wavefront distortion from gravity and mounting must be <1 / 4 wave; the step size for angular adjustment must be ≤0.1 μrad; and the angular stability must be ≤ 0.7 mrad over two hours. For LM4, 5, 7, and 8, the tip / tilt angular range is ±7.5 mrad, and alignment positioning linearity must be 3%. LM6 does not require active alignment during normal operation.

The switchyard and target area mirror-mount designs are the same (Figure 22). In this design, the isolating mounts provide stiff mirror support, yet flex to accommodate different coefficients of thermal expansion. The positioning flexures act as hinges for tip or tilt and as stiff members for mirror support.

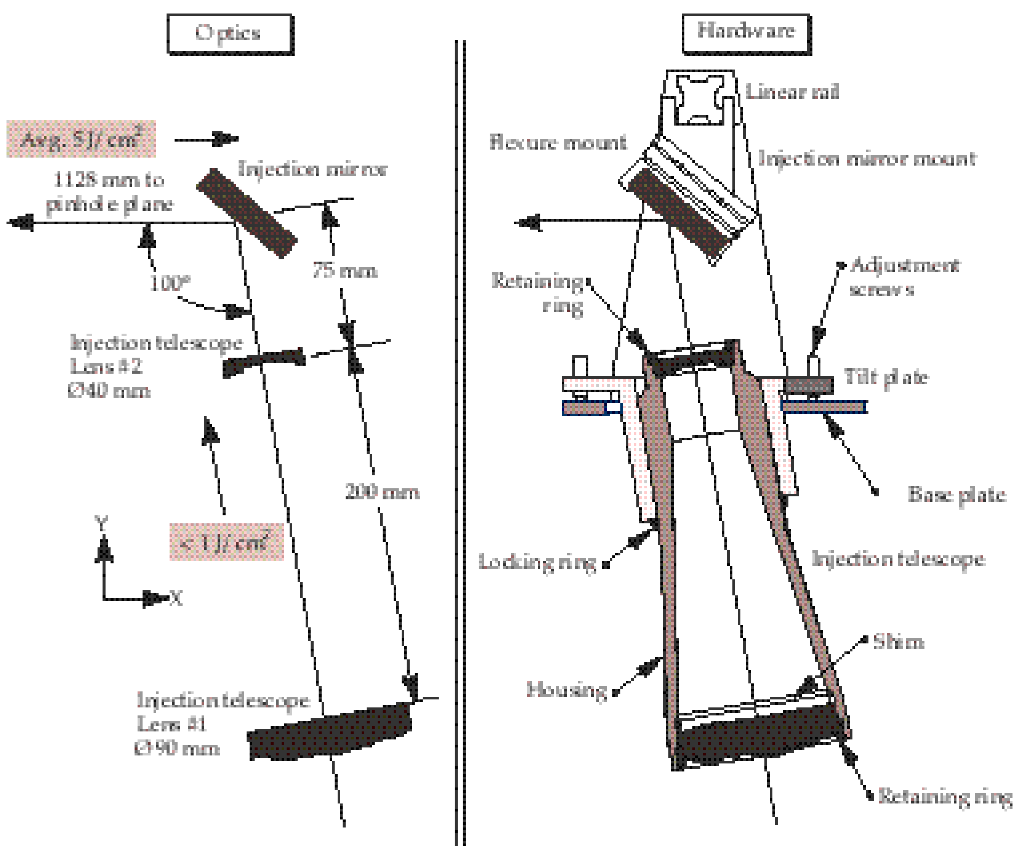


FIGURE 20. Layout for the injection telescope optics and hardware. (40-00-1097-2309pb01)

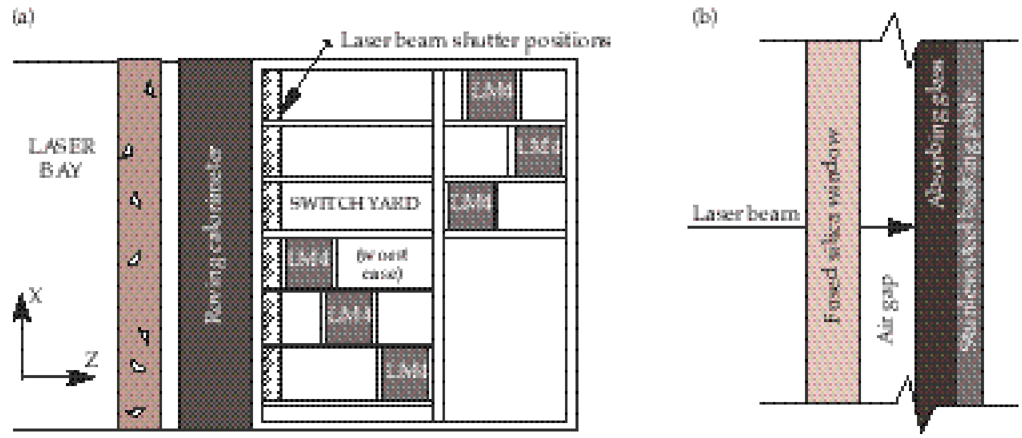


FIGURE 21. (a) The only position available to insert the laser beam shutters between the roving pick-off mirror / calorimeter enclosure and the switchyard mirror LM4. This view shows one cluster only. (b) The primary beam shutter components. (40-00-1097-2310pb01)

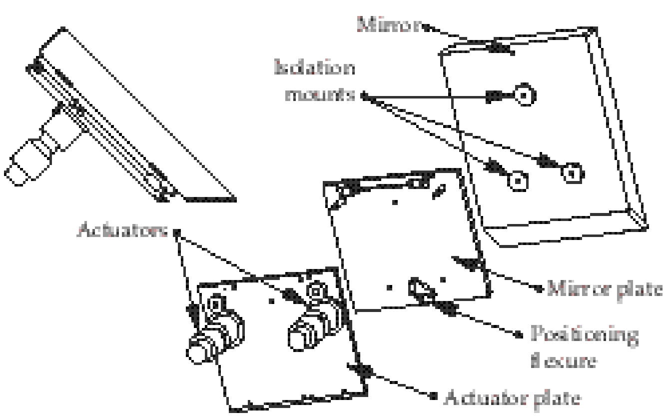


FIGURE 22. In addition to the mirror, a subassembly includes isolation mounts, positioning flexures, plates, and actuators. (40-00-1097-2311pb01)

All of these mirrors are mounted on kinematic equivalents to three-vee mounts. In the target area, LRUs are arranged in 1 × 2s for the LM6, 2 × 1s for the LM7, and 1 × 1s for the LM8. The LM6 LRUs are all identical; the mirrors are in plane and all have a 45° use angle. Six of these LRUs are in the upper mirror chamber and six are in the lower. The LRU enclosures are connected to the target area beam tubes to maintain cleanliness. There are 24 different LRUs for the LM7, with varying mirror offsets and use angles. The mirrors in each LRU have linear and angular offsets from each other. The mirror assemblies use a spacer frame to establish these offsets. The LM8 has eight different LRUs with eight different use angles. The LM8 mirrors are shimmed for use at eight different angles—from 18.8° to 34.4°—in the upper and lower mirror rooms.

Title II Activities

As Title II begins for NIF's beam transport system, we are ready to detail thousands of tons of structures, mechanisms, and vacuum vessels. Among our specific Title II activities, we will begin to procure materials that require a long lead time; prototype, fabricate, and test the LRUs' stability and maintainability; assess cleaning techniques and effects on fabrication; analyze how weather will affect switchyard stability during construction; and update the TSF to accommodate the 96-PAM baseline design. We will also complete details of LRU extraction and cavity closures, finalize mass production techniques for optics mounts, and freeze the interfaces with the target area beam layout. We will verify all analyses for the detailed design, as well.

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